

THE DISTRIBUTION OF VITAMIN A IN SOME CORN-MILLING PRODUCTS¹

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INTRODUCTION

It was shown by Coward in 1923 (1)³ that when whole yellow corn is used as the source of fat-soluble vitamins, large quantities are necessary to produce growth in rats which have been depleted of these vitamins. In more recent investigations Steenbock and Coward, (2, 21) have demonstrated that a much smaller quantity of whole yellow corn supplies sufficient vitamin A to produce a healthy condition in test animals if vitamin D is furnished in the basal ration. These results indicate, as suggested by the investigators, (1) that yellow corn is a remarkably poor source of vitamin D and that previous failure to promote growth on a low level of whole yellow corn was due to a deficiency of vitamin D rather than to a deficiency of vitamin A, and (2) that whole yellow corn is a rich source of vitamin A.

Millhouse and Croll,⁴ using the hand-dissected structures of whole yellow corn, found that the fat-soluble vitamins of yellow maize are located in the pigmented endosperm of the kernel. Steenbock and Coward (2, 21), also using hand-dissected corn, could state with greater certainty that vitamin A is concentrated in the endosperm of the yellow corn kernel, since in their study an irradiated basal diet furnished the antirachitic factor.

In the work here reported a qualitative and quantitative study of the distribution of vitamin A was made on all of the by-products recovered from the wet-milling process for the commercial separation of cornstarch from whole yellow corn.

At the time the milling products included in this study were obtained, yellow corn only was used by the milling company from which they were secured.⁵ The chemist reported a recovery of the whole yellow corn from the wet-milling process as follows:

Milling product	Per cent
Starch.....	65.0
Corn germs.....	7.0
Corn-germ meal.....	3.5
Crude corn oil.....	3.4
Grits.....	3.6
Gluten.....	10.0
Steep water (dried).....	5.0
Bran (reel slop).....	6.8
Gluten feed.....	25.4

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² Grateful acknowledgment is made to Hilda Croll Koser, under whose direction this study was begun.

³ Reference is made by number (italic) to "Literature cited," p. 779.

⁴ MILLHOUSE, L. E., and CROLL, H. Unpublished data.

⁵ Thanks are extended to the Staley Corn Products Co., Decatur, Ill., for the milling products used in this study.

The wet-milling process is a well-known commercial procedure for the preparation of cornstarch. The process as described by Rolfe (13) does not differ except in unimportant and minor details

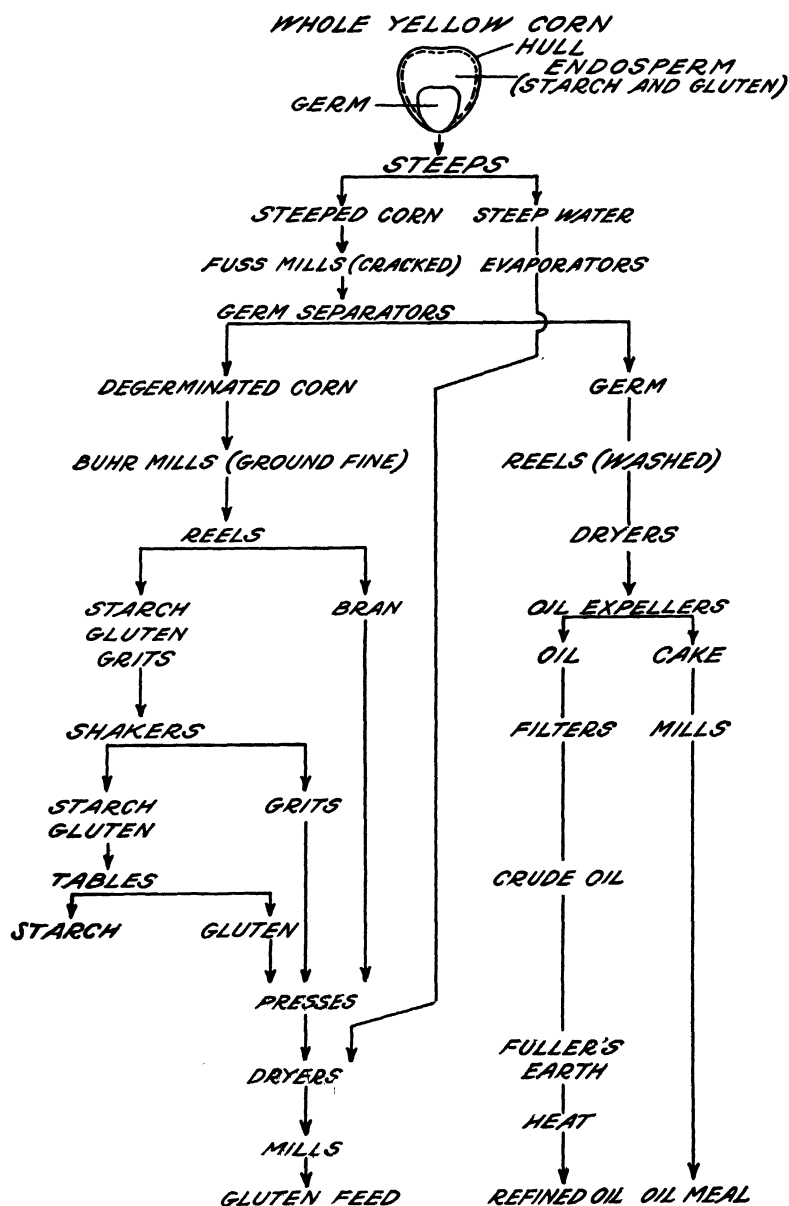


FIGURE 1.—Flow sheet indicating the relation of various corn-milling products to the structure of the corn kernel

from that employed by the milling company from which the products used in this work were obtained. It is almost entirely a physical rather than a chemical procedure involving comparatively

low temperatures and little chance for oxidation. The flow sheet in Figure 1 is a condensed diagram indicating the relation of the products here tested to the structure of the corn kernel and the general method of their separation by the wet-milling process.

EXPERIMENTAL PROCEDURE

Ophthalmia was developed in approximately 125 rats of the albino variety bred in the writers' own colony. Three series of animals were used in this study. In order to obtain rats of standard depletion in vitamin A, as Smith and Chick (19), Sherman and Storms (18), and other workers have found necessary, the mothers were given a diet low in this vitamin. For several weeks prior to and during breeding, and throughout the lactation period, a diet, essentially that used by Sherman (15, 16, 18), was fed. The diet consisted of two-thirds ground whole wheat and one-third whole-milk powder, with the addition of sodium chloride in the proportion of 1 per cent and meat scrap in the proportion of 5 per cent of the total weight of the wheat and

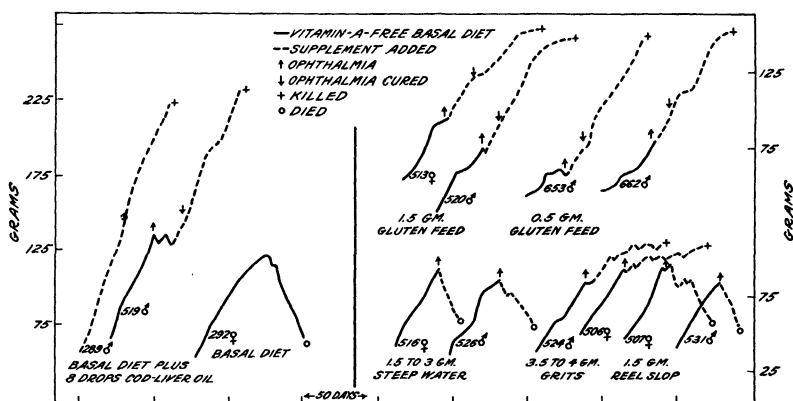


FIGURE 2.—Weight curves of rats receiving vitamin-A-free diets supplemented by various corn-milling products. When the vitamin-A-free basal diet was supplemented by 1.5 or 0.5 gm. of gluten feed daily, ophthalmia was cured; when the supplement was grits, ophthalmia was not cured and growth was very slow; when steep water or reel slop was used, ophthalmia was not cured and death resulted.

milk powder. On the second or third day after birth the litters were reduced to eight young each. The experimental period was started when the young were 28 to 30 days of age.

The usual methods for individual caging, feeding, and caring for experimental animals were employed. Raised-bottom cages were used. The rats were weighed once a week for the first three or four weeks and then two or three times a week after the development of ophthalmia and during the succeeding test period. The food intake was carefully noted at the time the animal was weighed and whenever a new supply of food was given. In order to reduce the error incurred by the scattering of food, 500 c. c. porcelain jars with screw tops, having an opening about 1½ inches in diameter, were used. The jars were filled about one-third full of food.

An attempt was made to determine the standard rate of growth for recovery of animals in series 2 and 3 by feeding cod-liver oil, 8 drops daily, after the appearance of ophthalmia. (Table 1 and fig. 2.) This is probably a better method by which to judge the extent of the

vitamin deficiency than the uninterrupted growth of an animal fed cod-liver oil from the beginning of the experimental period (9). (Table 2.) A "negative control" animal was maintained in each litter on the vitamin-A-free basal diet (Sherman, 17). (Table 3.)

TABLE 1.—*The effect of cod-liver oil on ophthalmia and growth of vitamin-A-deficient rats*

[Positive controls]

No. and sex of rat	Litter No.	Initial age	Initial weight	Time of ophthalmia incidence and weight of animal		Time of recovery from ophthalmia and weight of animal		Amount of supplement daily	Average weekly food intake (vitamin-A-free basal diet)		Duration of test period ^a	Final age	Final weight
				Days after experiment began	Body weight	Days after addition of supplement to diet	Body weight		Before addition of supplement	After addition of supplement			
		Days	Gm.		Gm.		Gms.	Drops	Gm.	Gm.	Weeks	Days	Gm.
519♂	6	31	56	27	128	7	142	8	61.0	74.0	6	114	231
645♀	10	24	40	34	45	11	82	8	19.0	41.0	7	119	157
671♂	13	30	34	28	71	9	119	8	38.6	69.0	5	111	165
658♀	12	29	44	31	78	9	119	8	42.2	63.0	5	111	162
817♀	17	29	55	30	158	6	176	8	65.5	83.0	3	79	205
821♂	17	29	64	34	164	7	186	8	68.2	68.5	4	79	220
832♂	14	29	53	38	168	10	206	8	65.6	67.7	4	83	228
839♀	15	29	46	28	120	12	158	8	55.5	50.6	4	83	179

^a The animals were all killed at the end of the test period.

TABLE 2.—*The prevention of ophthalmia and the growth of rats fed a vitamin-A-free basal diet supplemented by cod-liver oil*

[Positive controls]

No. and sex of rat	Litter No.	Initial age and weight		Amount of supplement fed daily	Average weekly food intake (vitamin-A-free basal diet)	Duration of test period ^a	Final age	Final weight
		Days	Gm.					
305♀	3	29	46	8	58.0	8	85	163
297♂	2	29	44	8	47.4	12	113	188
289♂	1	28	43	8	63.0	8	84	210
535♂	8	26	40	8	59.0	7	74	170
511♀	5	32	46	8	51.2	7	81	144
655♀	11	29	36	8	45.9	10½	103	158
672♂	13	30	23	8	56.4	10	101	165
840♀	15	29	39	8	60.1	8	83	165

^a The animals were all killed at the end of the test period.

TABLE 3.—*The effect of vitamin-A-free basal diet only on ophthalmia and growth of vitamin-A-deficient rats*

[Negative controls]

No. and sex of rat	Litter No.	Initial age	Initial weight	Time of ophthalmia incidence and weight of animal		Time of death from ophthalmia and weight of animal		Average weekly food (vitamin-A-free basal diet)		Duration of test period after incidence of ophthalmia ^a	Final age
				Days after experiment began	Body weight	Days after development of ophthalmia	Weight at death	Before development of ophthalmia	After development of ophthalmia		
		<i>Days</i>	<i>Gm.</i>		<i>Gm.</i>		<i>Gm.</i>	<i>Gm.</i>	<i>Gm.</i>	<i>Weeks</i>	<i>Days</i>
308♂	3	29	45	35	100	8	89	29.2	26.0	1	72
298♂	2	29	48	35	100	47	62	36.0	31.0	7	111
292♀	1	28	42	28	106	45	70	48.0	35.6	6	101
322♀	4	29	40	37	120	42	70	55.4	29.0	6	108
518♀	6	31	48	27	101	23	78	54.2	44.0	3	81
523♀	7	26	36	29	73	21	52	38.7	29.0	3	76
504♂	5	32	50	34	88	7	100	42.0	41.0	1	73
534♂	8	26	42	27	86	14	80	48.0	32.0	2	67
641♂	10	24	36	34	62	50	45	40.0	39.4	7	108
640♀	9	31	52	34	52	53	62	17.8	26.0	7	118
649♀	11	29	36	33	60	33	60	33.3	47.2	4	95
657♂	12	29	44	33	68	33	76	31.4	45.6	4	95
665♀	13	29	46	28	68	38	63	32.5	31.0	5	95
844♀	16	28	40	28	121	28	104	63.0	54.0	4	84
820♂	17	29	62	14	118	26	153	75.0	71.0	4	71
852♂	19	30	58	28	158	28	123	80.0	49.5	4	86
836♂	15	29	42	24	120	16	120	52.0	62.0	2	69
828♀	14	29	47	27	125	13	130	50.0	70.0	2	69

^a The test period terminated with the death of the animal in each case.

A vitamin-A-free basal food was given the test animals, which they were allowed to eat ad libitum. The antirachitic factor was supplied in the food by irradiation in shallow agate pans at a distance of 20 inches from the lamp for one-half hour. The food was stirred at the end of each 15 minutes of irradiation (21, 20). A Hanovia luxor mercury arc lamp was used.

The basal diet was composed of the ingredients in the percentage amounts given below:

	Per cent
Extracted casein.....	18
Osborne-Mendel salt mixture.....	4
Crisco ⁶	20
Starch.....	57
Sodium chloride.....	1

The casein was purified by the alcohol-extraction method of Osborne and Mendel (10, 11). It was then air-dried for several days and subsequently spread out in shallow pans and heated from 8 to 12 hours in gas ovens at 120° C. (Drummond (3, 6, 7).)

The basal food was mixed and stored in glass jars in a refrigerator. If it was to be used within a short time it was first irradiated and then stored in the refrigerator. A week's supply was usually irradiated at one time.

The water-soluble vitamin-B factors were supplied by dried brewers' yeast, five-tenths gram per animal daily, fed separately.

The development of definite ophthalmia was taken as a sign of vitamin-A deficiency. (Morgan (9), Steenbock and Coward (21),

⁶ Drummond (5), Daniels and Laughlin (4).

Steenbock, Sell, and Buell (22).) With the depleted animals used, definite eye symptoms almost invariably preceded cessation of growth and developed from 25 to 35 days after the experimental period began.

As soon as the eye symptoms became persistent, the test food was added to the diet. It was given separately in definitely weighed portions, or later, especially in the case of foods not entirely eaten when fed separately, as a definite part of the basal diet. The supplement replaced the same percentage of starch, or Crisco, or parts of both the starch and the Crisco; when thus mixed with the basal food, the test material was added after the irradiation of the purified ingredients. (Willimott and Wokee (23).) When fed separately the daily portion of the test food was moistened with distilled water immediately before feeding, for all of the foods, with the exception of the oils, were extremely dry and powdery, and the moistening reduced possible loss by air drafts.

The vitamin-A value of the test food was judged chiefly by the minimal dosage necessary for the ultimate cure of the eyes. (Steenbock and Coward (21).) A resumption of body growth was also observed.

EXPERIMENTAL RESULTS

In order to make this investigation quantitative in nature, it was necessary first to conduct a preliminary qualitative study of the corn-milling products. Each of the products was fed in accurately weighed amounts of 1.5 gm. daily to at least two rats in which ophthalmia had developed. The results obtained in this first series of animals as indicated by the ultimate positive or negative cure of ophthalmia were without exception as shown in Table 4.

TABLE 4.—*The effect on ophthalmia of various corn-milling products when used as supplements to a vitamin-A-free diet*

Supplement	Amount fed daily per animal	Number of rats	Effect on ophthalmia	Effect on growth
	<i>Grams</i>			
Steep water	1.5	3	Not cured	Decline and death.
	2.3	1	do	Do.
	3.0	1	do	Do.
Reel slop	1.5	3	do	Do.
	1.8	1	do	Do.
	2.3	1	do	Do.
Grits	1.5	2	do	Very slow decline; all but 1 lived.
	2.6	1	do	
	3.4	1	do	
	4.0	1	do	Normal growth.
Gluten	1.5	2	Rapid cure	
	1.0	5	do	
	.5	2	do	Do.
	.25	3	do	Do.
Gluten feed	.1	3	Not cured	Growth finally arrested; 1 died.
	1.5	8	Rapid cure	Normal growth.
Germ	1.5	3	Not cured	Slowly declined; 1 died.
	2.0	4	do	All 4 died.
Germ meal	1.5	2	do	Rapid decline; death.
	3.0	2	do	Do.
Crude corn oil	1.5 to 1.7	5	Slow cure	Lived and grew.
	.9 to 1.2	6	do	Do.
	.28 to .4	3	Not cured	All died.
Refined corn oil	1.5	2	do	Decline and death.
	1.0	1	do	Do.
	.6	1	do	Do.
	1.5	5	Rapid cure	Normal growth.
	1.0	8	More slowly cured	Do.
Whole yellow corn	.75	5	Never permanently cured.	Growth approaching normal.
	.5	5	do	Growth arrested; 3 died.
	.25	5	Not cured	Low rate of growth; all died.

In the case of steep water, reel slop, and grits, which were more or less poorly consumed as separate fractions, an attempt was made to feed at a higher level in order to test for traces of the vitamin. These three by-products were fed, therefore, as 50 per cent of the diet, replacing the same percentage of starch in the basal ration. As a result, the daily dosage was increased as shown in Table 4. In each case, as the table shows, despite the higher level reached in the feeding of the supplement, there was neither a cure of ophthalmia nor a resumption of growth. The animals fed the steep water exhibited extremely sore eyes, with considerable pus and hemorrhage, and in some instances complete atrophy of the eyeball. The feces were watery and had the characteristic brown color of the steep water. The animals receiving the reel slop or bran supplement developed extreme ophthalmia to the same extent, apparently, as those on the steep water. The feces, however, were very large, due, probably, to the great extent of indigestible crude fiber in the reel slop. The grits supplement was better consumed than the steep water or the reel slop. There was a slow development of extreme ophthalmia in the case of animals on this fraction, but at no time were the eyes cured. It is apparent from these results, that the three by-products named above are almost if not totally lacking in vitamin A. (Fig. 2.)

Gluten feed in 1.5-gm. daily amounts produced a rapid cure of ophthalmia in eight rats. (Table 4.) The gluten feed is composed of reel slop, grits, steep water, and gluten. (Fig. 1.) Since all these products except gluten when tested separately were almost if not totally lacking in vitamin A, it seemed necessary only to test the gluten in a quantitative manner for this vitamin. The various levels of feeding used and the results obtained are shown in Table 5.

TABLE 5.—*The effect of feeding corn gluten on ophthalmia and growth of vitamin-A-deficient rats*

No. and sex of rat	Litter No.	Initial age	Initial weight	Time of ophthalmia incidence and weight of animal		Time of recovery from ophthalmia and weight of animal		Ophthalmia not cured		Amount of supplement fed daily	Average weekly food intake (vitamin-A-free basal diet)		Duration of test period *	Final age	Final weight
				Days after experiment began	Body weight	Days after addition of supplement to diet	Body weight	Days after addition of supplement to diet	Body weight		Before addition of supplement	After addition of supplement			
		Days	Gm.		Gm.		Gm.		Gm.	Gm.	Gm.	Gm.	Weeks	Days	Gm.
306♂	3	29	46	39	98	10	110	-----	-----	1.50	41.0	44.8	8	120	170
294♀	1	28	43	28	113	14	144	-----	-----	1.50	35.0	54.3	7	112	176
521♂	7	26	31	29	70	10	93	-----	-----	1.00	45.5	44.8	8	109	138
529♂	8	26	42	29	89	10	102	-----	-----	1.00	56.5	55.5	8	109	182
533♂	8	26	38	27	74	10	84	-----	-----	1.00	39.2	48.4	8	109	152
508♂	5	32	50	32	106	6	112	-----	-----	1.00	58.0	59.0	7	115	168
515♂	6	31	50	32	114	6	123	-----	-----	1.00	53.0	60.0	7	114	195
504♂	5	32	36	34	88	14	122	-----	-----	1.00	42.0	50.0	6	115	172
653♂	11	29	44	29	54	6	71	-----	-----	.50	33.5	44.1	8	117	160
663♂	12	29	46	33	75	14	108	-----	-----	.50	31.4	44.7	8	117	175
650♂	11	29	40	32	61	14	77	-----	-----	.25	29.3	37.1	8	117	136
660♂	12	29	44	33	83	9	102	-----	-----	.25	27.0	42.0	8	117	147
666♀	13	29	42	32	66	14	85	-----	-----	.25	36.8	40.0	8	117	122
661♂	12	29	43	33	72	-----	-----	34	95	.10	36.6	37.6	5	96	95
667♀	13	29	50	33	78	-----	-----	55	121	.10	43.1	37.2	8	117	121
651♂	11	29	37	33	58	-----	-----	55	93	.10	37.7	38.0	8	117	93

* All animals were killed except 661 which died with ophthalmia.

As previously stated, gluten is recovered in quantity equivalent to about 10 per cent of the whole corn. If then all the vitamin A of the whole yellow corn were concentrated in the gluten, similar results should be obtained with 0.1 gm. of gluten and 1 gm. of whole yellow corn fed daily. One gram of the whole yellow corn fed daily gave a comparatively rapid cure of ophthalmia and produced normal growth. It was found, however, that 0.1 gm. of gluten was not sufficient to cure or even to arrest ophthalmia. (Fig. 3 and Table 5.) One-fourth of a gram of gluten, however, cured the eye lesions, and, in addition, produced growth in the vitamin-A-depleted rats. Some of the vitamin, therefore, must have been lost in the separation of gluten from the corn or is present in other structures of the corn kernel.

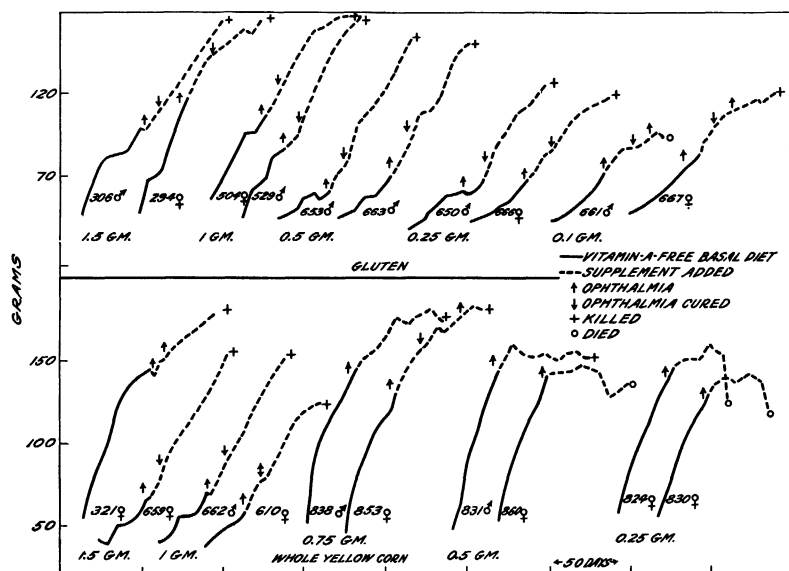


FIGURE 3.—Weight curves of rats receiving vitamin-A-free diets supplemented by various quantities of gluten and whole yellow corn

The results of the preliminary study indicated that some of the vitamin A of corn occurs in the germ structure of the kernel. A cure of ophthalmia was demonstrated with the crude corn oil. The germ itself, however, and the germ meal at the levels fed did not cure the eyes. The animals barely maintained weight and eventually died. The animals given the germ fared better than those given the germ meal. (Fig. 4.) But since a daily intake of 2 gm. of the germ was followed at best by only a slight improvement in the eye condition (Table 4), it was concluded that the small amount of vitamin A present in the germ had to be pressed out in the germ oil before its presence could be detected. The results of the quantitative study of crude corn oil, which are summarized in Table 6, show that crude corn oil is comparatively rich in vitamin A. (Fig. 4.)

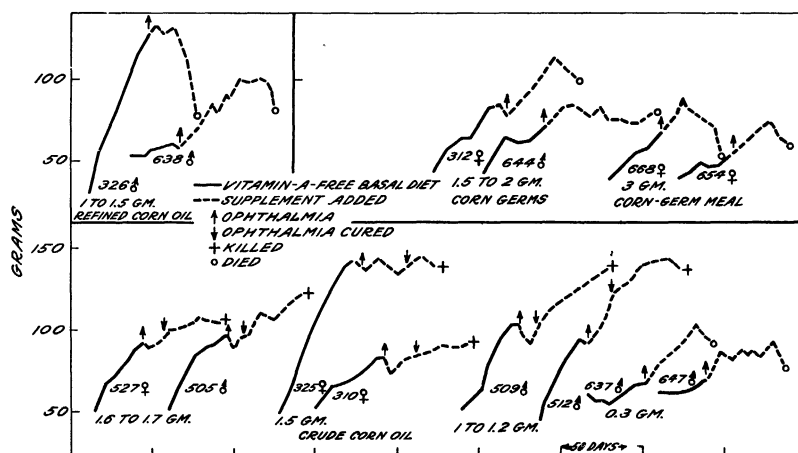


FIGURE 4.—Weight curves of rats receiving vitamin-A-free diets supplemented with various corn-milling products. When the vitamin-A-free basal diet was supplemented with one or more grams daily of crude corn oil, ophthalmia was cured and the animals lived; when the supplement was corn germs, corn-germ meal, or refined corn oil, ophthalmia was not cured and death resulted.

TABLE 6.—The effect of crude corn oil on ophthalmia and growth of vitamin-A-deficient rats

No. and sex of rat	Litter No.	Initial age	Initial weight	Time of ophthalmia incidence and weight of animal		Time of recovery from ophthalmia and weight of animal		Ophthalmia not cured		Amount of supplement fed daily	Average weekly food intake (vitamin-A-free basal diet)		Duration of test periods *	Final age	Final weight
				Days after experiment began	Body weight	Days after addition of supplement	Body weight	Days after addition of supplement to diet	Body weight		Before addition of supplement	After addition of supplement			
		Days	Gm.		Gm.		Gm.		Gm.	Gm.	Gm.	Gm.	Weeks	Days	Gm.
310♂	3	29	43	38	80	22	82	-----	-----	1.5	35.0	17.5	8	120	90
325♂	4	29	49	48	138	28	140	-----	-----	1.5	46.0	31.0	8	119	140
514♂	6	31	52	29	92	12	98	-----	-----	1.55	45.5	16.0	8	114	124
505♂	5	32	47	34	98	14	96	-----	-----	1.66	45.0	17.0	8	120	124
527♀	7	26	34	29	84	12	92	-----	-----	1.7	48.0	19.0	7	109	106
525♀	7	26	36	32	82	9	100	-----	-----	1.0	41.0	31.0	7	109	106
509♂	5	32	53	29	105	12	100	-----	-----	1.0	51.0	40.0	8	115	138
512♂	6	31	50	29	88	12	122	-----	-----	1.2	52.0	44.4	8	114	136
642♂	10	24	57	34	58	27	93	-----	-----	1.0	34.4	28.0	9	120	132
634♂	9	31	45	38	47	40	102	-----	-----	.9	23.6	26.7	8	127	124
643♂	10	24	33	34	54	30	86	-----	-----	1.0	35.0	34.4	9	120	118
646♀	10	24	35	34	58	-----	-----	46	74	.4	36.6	25.2	6½	104	74
637♂	9	31	55	38	64	-----	-----	52	87	.28	23.0	17.5	7½	111	87
647♂	10	24	35	34	38	-----	-----	51	57	.3	14.0	19.2	7½	109	57

^a All animals were killed except 646, 637, and 647, which died with ophthalmia.

Refined corn oil was not only incorporated in the basal diet to replace the 20 per cent Crisco, but was also fed separately in daily fractions. From the results shown in Table 4 and Figure 4 it is evident that there is little if any vitamin A in refined corn oil. It may be concluded that there is sufficient heat under oxidative conditions involved in the refining process to destroy all of the vitamin A that may have been present in the crude corn oil.

A quantitative study of the unmilled yellow corn was undertaken. The results obtained (Table 7) show that 1 gm. daily, or approximately

11 per cent, is the minimum requirement for permanent cure of ophthalmia and normal growth. Temporary cure of the eyes was obtained with 0.75 gm. daily, or approximately 9 per cent, and even with as little as 0.5 gm. daily, but the eyes again became extremely sore, a general decline occurred, and death resulted in most cases.

TABLE 7.—*The effect of (ground) whole yellow corn on ophthalmia and growth of vitamin-A-deficient rats*

No. and sex of rat	Litter No.	Initial age	Initial weight	Time of ophthalmia incidence and weight of animal		Time of recovery from ophthalmia and weight of animal		Ophthalmia not cured		Amount of supplement fed daily	Average weekly food intake (vitamin-A-free basal diet)			Duration of test periods	Final age	Final weight
				Days after experiment began	Body weight	Days after addition of supplement to diet	Body weight	Days after addition of supplement to diet	Body weight		Before addition of supplement	After addition of supplement				
		Days	Gm.		Gm.		Gm.		Gm.	Gm.	Gm.	Gm.	Weeks	Days	Gm.	
321♂	4	29	54	44	143	5	154	—	—	1.50	60.3	50.7	5.5	112	180	
307♂	3	29	47	39	98	10	110	—	—	1.50	39.1	46.0	7.5	120	176	
304♂	2	29	50	35	90	11	95	—	—	1.50	33.2	40.4	8	120	178	
659♀	12	29	42	33	68	6	79	—	—	1.50	28.8	39.0	8	117	153	
652♀	11	29	48	33	66	9	82	—	—	1.50	25.6	43.0	8	117	155	
656♀	11	29	44	33	62	7	89	—	—	1.0	27.6	47.0	8	117	178	
662♀	11	29	42	41	70	7	91	—	—	1.0	27.0	43.7	8	117	167	
664♀	12	29	42	31	74	11	96	—	—	1.0	29.2	47.5	8	117	162	
669♀	13	29	36	33	68	7	76	—	—	1.0	26.2	43.3	8	117	148	
670♀	13	30	32	30	58	9	78	—	—	1.0	46.7	45.4	8	117	135	
829♀	14	29	49	28	133	12	147	—	—	1.0	66.0	71.5	8	113	170	
837♀	15	29	44	28	123	12	132	—	—	1.0	63.5	74.6	8	113	167	
845♀	16	28	51	28	133	18	147	—	—	1.0	59.2	66.7	8	110	178	
822♂	17	29	63	30	170	—	—	56	198	.75	78.0	48.0	8	115	198	
838♂	15	28	48	28	140	—	—	56	174	.75	67.7	49.1	8	113	174	
846♀	18	28	39	28	114	—	—	46	109	.75	58.0	44.3	7	102	109	
853♀	19	30	51	28	136	—	—	54	181	.75	70.5	72.0	8	112	181	
856♀	19	30	53	28	134	—	—	54	167	.75	60.0	52.0	8	112	167	
823♀	17	29	60	30	149	—	—	56	168	.50	70.2	75.2	8	115	168	
831♂	14	29	54	28	147	—	—	56	147	.50	63.2	44.6	8	113	147	
847♂	18	28	57	34	156	—	—	41	153	.50	52.4	57.1	6	115	153	
854♂	19	30	51	32	157	—	—	55	158	.50	50.1	50.0	8	117	158	
860♀	20	30	51	32	145	—	—	48	138	.50	60.0	49.0	7	110	138	
824♀	17	29	58	30	142	—	—	37	128	.25	70.5	74.4	5	96	128	
830♀	14	29	54	28	128	—	—	37	116	.25	57.0	61.4	5	94	116	
848♀	18	28	40	36	127	—	—	20	103	.25	61.6	47.3	3	84	103	
855♀	19	30	46	29	127	—	—	35	133	.25	59.8	67.4	5	94	133	
861♂	20	30	56	34	141	—	—	29	140	.25	60.2	66.2	4	93	140	

¹ Animals 846, 847, 854, 860, 824, 830, 848, 855, and 861 died; the rest were killed.

As a result of this study a flow sheet similar to that in Figure 1 may be drawn to indicate the distribution of vitamin A in the same milling products. Such a sheet is shown in Figure 5.

The condition of typical animals while on a diet deficient in vitamin A and after recovery from the effects of vitamin-A depletion is shown in Figure 6.

THE RELATION BETWEEN VITAMIN-A-CONTENT AND YELLOW PIGMENTATION

The high concentration of vitamin A in highly pigmented products of yellow corn, gluten, and crude corn oil as found in this study demonstrates the association of vitamin A with yellow pigmentation. Coward (*1*), in 1923, stated that some lipochrome, generally carotin, is always associated with the vitamin A in plant tissues and that where the carotin is found, particularly carotin exposed to sunlight,

there also the vitamin may be expected to be present. However, various other workers, as for example, Palmer and Kennedy (12) in 1921, Steenbock, Sell, and Buell (22) in 1921, and Drummond and Coward (7) and Rosenheim and Drummond (14) in 1920, have noted exceptions in the association of vitamin A with yellow pigmentation.

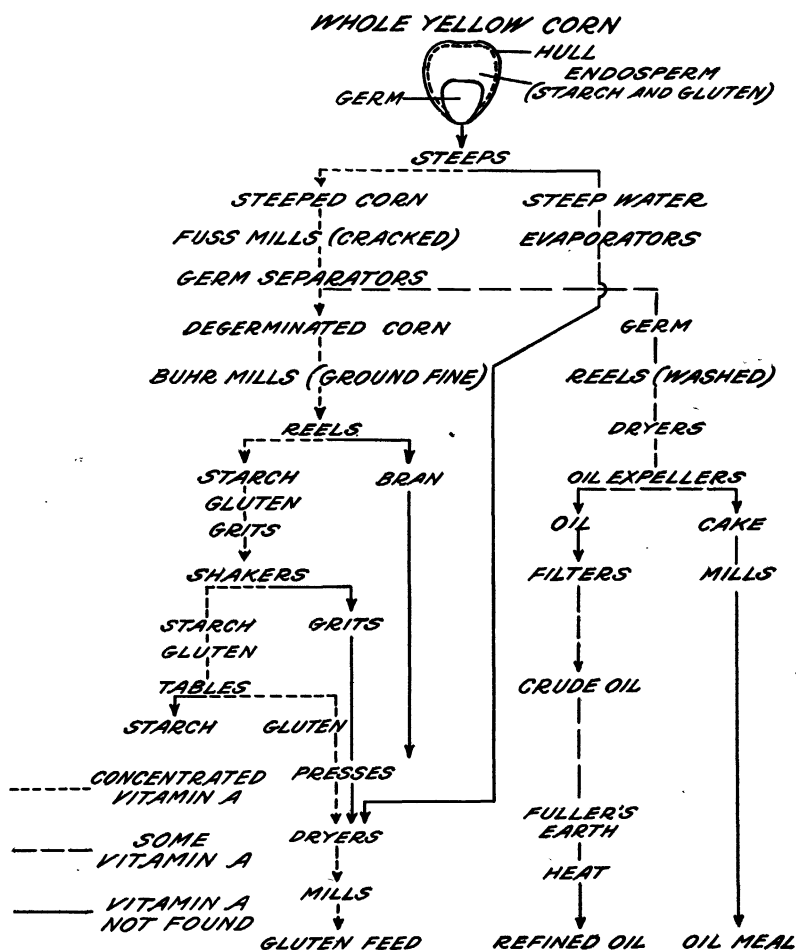


FIGURE 5.—Flow sheet indicating the distribution of vitamin A in various corn-milling products

Hauge and Trost (8), in a recent inheritance study of the association of vitamin A and yellow endosperm kernel, concluded that any genetic relationship existing between these two factors must be one of close linkage. They found that vitamin A was transmitted exclusively with yellow endosperm through the process of crossing and segregation.

SUMMARY

The rate of growth, and the recovery or nonrecovery from ophthalmia of vitamin-A-depleted rats were observed when their vitamin-A-deficient basal diets were supplemented with whole yellow corn and with various corn-milling products.

Whole yellow corn was found to be rich in vitamin A. Rapid growth was obtained when amounts of 1.5 gm. per animal were fed daily. The minimal amount needed to cure ophthalmia was 1 gm. daily, or approximately 11 per cent of the total food intake.

Gluten feed administered in amounts of 1.5 gm. daily rapidly cured the ophthalmic eyes of vitamin-A-depleted rats. Three of the four milling products that constitute the gluten feed—namely, steep water, reel slop, and grits—failed in every instance to effect a cure; gluten, the fourth constituent, was found to be extremely potent. The minimum amount of gluten required to cure ophthalmia was 0.25 gm. fed daily, and this amount also produced normal growth.

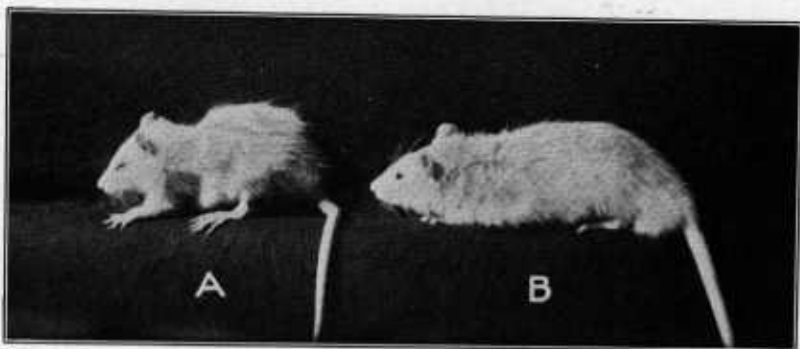


FIGURE 6.—Typical animals representing the vitamin-A-deficient rat, and the rat which has recovered from vitamin-A deficiency. A.—In the case of rat 531♂ ophthalmia was not arrested and a decline in growth resulted when the diet consisted of steep water, grits, reel slop, corn germs, corn-germ meal, and refined corn oil as sole sources of vitamin A. B.—When ophthalmic animals were fed yellow corn, gluten, gluten feed, or crude corn oil, the ophthalmia was cured and there was a resumption of growth, the animals finally appearing like rat 519♂

This finding shows that vitamin A is concentrated in the endosperm of the yellow-maize kernel. It furthermore unquestionably indicates that the vitamin-A concentration is greatest in that part of the endosperm lying next to the seed coats—the pigmented, nitrogenous outer layer of the endosperm.

Crude corn oil was found to cure ophthalmic rats when administered in daily doses of 1.5 gm. Corn germs, the source of the crude corn oil, were found to be so devoid of vitamin A that no cure could be obtained even when they were fed at a level of 2 gm. daily. The germ meal was found totally lacking in vitamin A. It was concluded that the small amount of vitamin A not found in the gluten is concentrated in or associated with the corn oil of the yellow corn germ and that it follows the oil in its removal from the germ. Refined corn oil was found to be totally lacking in antiophthalmic qualities and hence in vitamin A.

A high vitamin-A content was found associated with yellow pigmentation.

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